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CATCHES OF MARINE DIATOMS AND DINOFLAGELLATES TAKEN BY BOAT IN SOUTHERN CALIFORNIA WATERS IN 1926

BY

WINFRED EMORY ALLEN

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INTRODUCTION

This is the fifth in a series of papers dealing with material collected by boat at two definite stations and at numerous miscellaneous stations in the southern California region, mostly in the Gulf of Santa Catalina and near La Jolla. The methods of work have remained the same as in 1921 (Allen 1923*a*), and changes in routine have occurred mainly in frequency of collecting and in choice of levels when making subsurface collections.

Most of the southern California boat work of 1926 was done in the summer months, but some catches were made as early as March and some as late as October. Most of them were taken by use of the boat owned by the Scripps Institution, the "Thaddeus" (now the "Scripps"), but one group of surface catches was taken by Dr. G. F. McEwen during a trip on the U. S. S. "Pioneer" while she was engaged in field work for the United States Coast and Geodetic Survey. Surface collections were taken without particular attention to movement of the boats, but all subsurface collections were necessarily taken while the boat was either drifting or at anchor.

Work on the "Thaddeus" in the first half-year was done with the same equipment as in former years (Allen, 1923*a, b,* Dorman, 1927, Sleggs, 1927), but after the fourth regular trip to stations 1 and 2 in June, interruptions due to difficulty in handling the heavy Kofoid closing bucket led to the discontinuance of its use. Subsurface work at all stations, on and after the last trip in June, was done with the much smaller and lighter Allen closing bucket (Allen, 1927*a*). Use of the bucket of smaller size made necessary some change in procedure in subsurface sampling. This change consisted essentially in hauling twice at each level to get the total of ten liters of water for filtration, and in limiting the size of the sample to ten liters, instead of the twenty liters obtained with the Kofoid bucket. These changes proved to be very helpful. The lighter bucket was so much more easily handled that there was great saving in time (even with two hauls at each level), and there was no trouble with hoisting equipment, such as had interrupted work with the heavier closing bucket. On this account more subsurface samples were regularly taken at each fixed station. In the regular routine of sampling, eleven samples were taken, nine at five-meter intervals from surface to forty meters, one at fifty meters, and another at sixty meters. This routine was carried through twelve successive collecting trips without a break, a feat never accomplished with the heavier closing bucket. Two days of each week

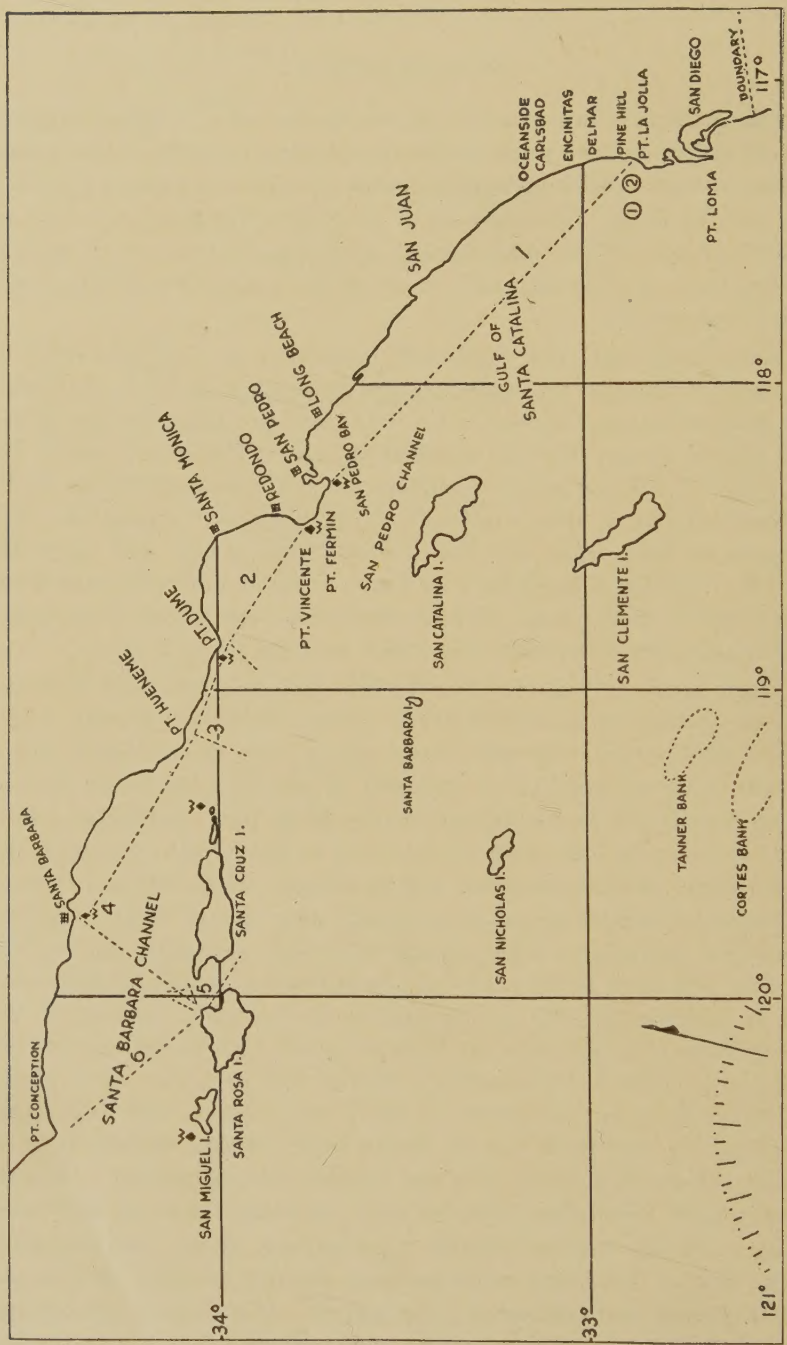

Fig. 1. Region of boat work in 1926. Numerals indicate sections of August cruise. Numerals in circles indicate standard (annual) stations.

were designated for subsurface collecting of plankton at the two fixed stations. Other days were devoted to hydrographic, chemical, and general biological work.

Collecting at the two fixed stations was suspended in August in order to make a cruise to the Santa Barbara region. On this cruise collections were made at one hundred and forty-eight temporary stations. At a few stations subsurface catches were made.

In addition to collecting done at the fixed stations and on the cruise, a great many samples were taken at different times and places. Most of this collecting was done at the surface level.

STATIONS 1 AND 2

The regular plankton collecting at stations 1 and 2 (respectively ten and five miles seaward from the Scripps Institution pier) was begun on June 3 and ended on September 13 in 1926. Collections were made on two days in each week except for a two weeks' interruption in June, due to failure in handling the Kofoid bucket, and, except for irregularity after July, due to scarcity of plankton and pressure of other work. Collections were made on sixteen days at station 1 and on the same sixteen days plus one other at station 2. No catches were made at the thirty-five-meter level at either station on June 3 and 7. With that exception catches were made as rapidly as possible at the surface, at five-meter intervals to forty meters, and at fifty- and sixty-meter levels, to constitute a standard series at each time of collecting. Work was begun usually at station 1 in the earlier part of the forenoon and finished at station 2 less than three hours later.

Gross Features of Distribution

Most obvious of the gross features of distribution in the two localities is the great preponderance of diatoms over dinoflagellates at all levels at both stations (tables 1, 2). In fact, with the one exception of the surface level at station 2, the combined total of dinoflagellate cells for the sixteen catches at any level was less than the average number of diatom cells taken in the same sixteen catches at that level.

The two groups of organisms agreed in having a somewhat larger average of production at thirty meters than they had at most of the other levels, but they differed in that dinoflagellate production was best at the surface while the diatoms showed greater abundance at several lower levels than at the surface.

TABLE 1

NUMBERS PER LITER OF DIATOM CELLS IN SAMPLES OF SEA WATER AT DIFFERENT DEPTHS IN SUMMER, 1926, NEAR LA JOLLA

	Station 1. 16 catches				Station 2. 16 catches			
Depth meter	Total 16 catches	Average to catch	Largest catch	Least catch	Total 16 catches	Average to catch	Largest catch	Least catch
0	83,382	5,211	50,042	110	59,328	3,708	17,204	132
5	34,620	2,164	9,240	0	28,588	1,787	12,720	0
10	85,037	5,315	55,181	0	27,336	1,708	10,640	0
15	58,406	3,650	27,680	0	34,854	2,178	10,560	0
20	95,727	5,983	44,637	80	87,621	5,476	31,560	0
25	230,952	14,434	74,226	0	129,936	8,121	36,280	0
30	835,663	52,229	276,088	160	355,876	22,242	120,800	0
35	697,105	49,793	439,737	880	114,828	8,202	40,800	80
40	245,170	15,323	45,893	2,080	107,690	6,856	26,128	160
50	117,396	7,337	21,036	480	40,096	2,506	20,940	0
60	92,994	5,812	30,251	0	17,716	1,107	2,160	22

TABLE 2

NUMBERS PER LITER OF DINOFLAGELLATE CELLS IN SAMPLES OF SEA WATER AT DIFFERENT DEPTHS IN SUMMER, 1926, NEAR LA JOLLA

	Station 1. 16 catches				Station 2. 16 catches			
Depth meter	Total 16 catches	Average to catch	Largest catch	Least catch	Total 16 catches	Average to catch	Largest catch	Least catch
0	2,430	152	374	0	5,998	375	1,276	0
5	1,624	101	240	0	1,230	77	400	0
10	1,366	85	264	0	1,918	120	560	0
15	488	30	240	0	1,174	72	308	0
20	1,396	87	264	0	576	36	400	0
25	818	51	160	0	954	60	240	0
30	2,361	147	665	0	1,116	70	240	0
35	1,510	107	480	0	320	23	160	0
40	1,322	83	352	0	336	21	88	0
50	896	56	160	0	474	30	160	0
60	724	45	220	0	706	44	160	0

DINOFLAGELLATES

The highest number of dinoflagellates taken in any catch was 1,276 at station 2, surface level. Many catches yielded none. At no level was the average production as great as 400 cells to the liter. In a series so short as this, the significance of differences in numbers so small is slight, and definite conclusions are not warranted.

Perhaps the need for caution may be realized best after examining the list of largest catches in table 2. From this list it appears that at each level at least one catch was taken which was larger than the average of the catches at nearly all of the other levels. This evidence

shows that each level, at some time in the period of sampling, had sustained a population greater than the mean of some other level, wherefore it is improper to assume that the conditions might not have been reversed at periods lacking observation. However, the taking of larger numbers at or near the surface occurred with frequency sufficient to support the view expressed by Sleggs (1927, p. 99) that the surface region is most productive of dinoflagellates. There is also substantial agreement as to distribution at different levels between table 2 and Sleggs's table of averages on page 99. Such similarity in distribution in different years greatly strengthens the view that the conditions of normal distribution at these two stations are fairly well represented.

Table 2 shows very plainly that two levels, the surface and thirty meters, marked the more productive regions at station 1. This demarcation is less distinctly indicated at station 2 where three other levels near the surface showed more than the thirty-meter level. The Sleggs table, just mentioned, also exhibits a preponderance of dinoflagellates at the surface and the thirty-meter levels.

Species

Few species of dinoflagellates were represented at stations 1 and 2 in 1926 catches. Most of these were poorly marked and insignificant in appearance. *Gonyaulax polyedra* St. was the most distinct but it was mostly confined to the surface or near it. In general, it may be said that 1926 was a very poor year for dinoflagellates at these stations in the summer season.

DIATOMS

General Features

The general features of distribution of diatoms at stations 1 and 2 are shown in table 1 and figure 1. The most important of these features are the greater productivity of station 1 at all levels, the preponderance of production at the surface and the thirty-meter levels, and the constancy of yield at the surface and the forty-meter levels.

Larger Numbers at Station 1

In the five years of collecting at the two stations in the summer season, two years have indicated a greater productivity at station 2 (5 miles, Allen, 1923*a*, *b*) ; one year has shown a similarity in quantities as a whole though differing considerably at different levels (Dorman, 1927) ; one year, with the exception of two levels, has shown a greater productivity at station 1 (10 miles, Sleggs, 1927) ; and one

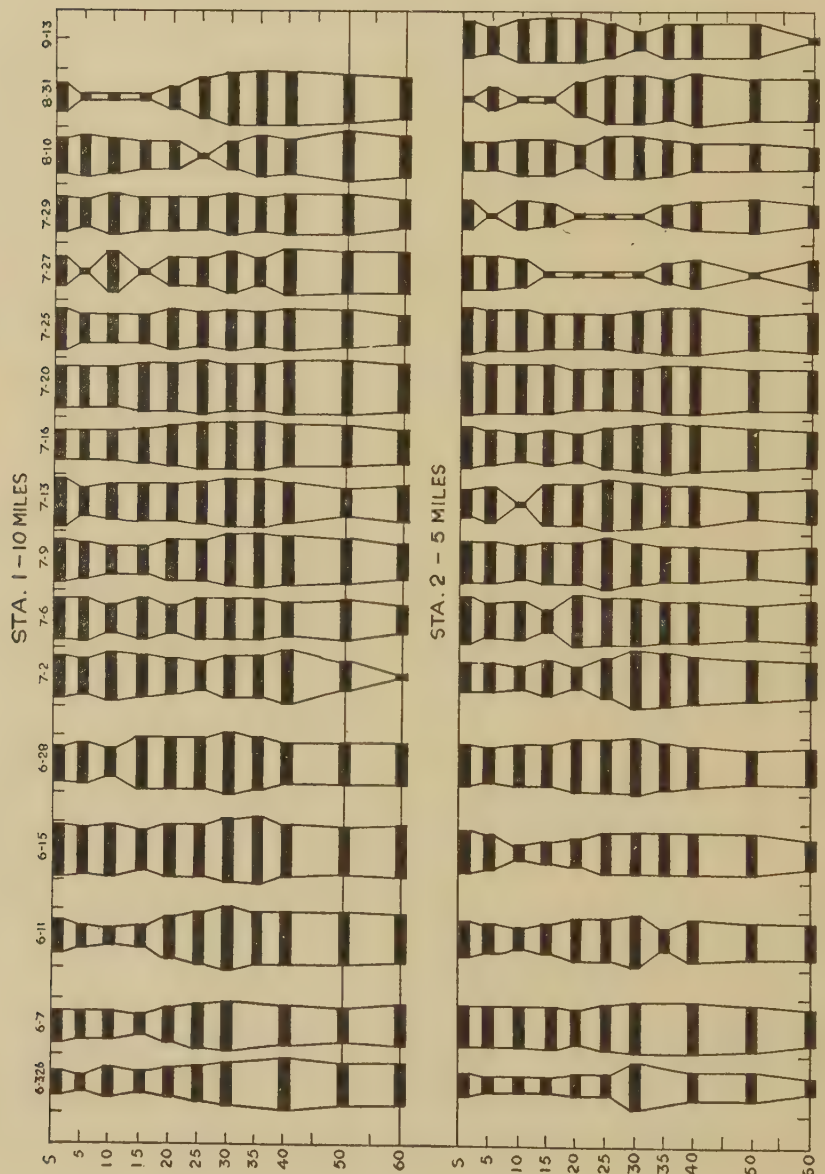

Fig. 2. Surface and subsurface distribution of diatoms at Stations 1 and 2. Cross-bars represent logarithms of numbers per liter. Numerals indicate dates, and depths in meters.

year, now under discussion, has shown greater productivity at station 1 at all levels. No boat work was done in 1925 and the five years are not consecutive.

It should be noted and carefully remembered that for no two years of the five are the series strictly comparable. In 1921 only two levels (surface and twenty meters) were sampled, but collections were made almost daily through most of June and part of July. In 1922 operations were essentially similar except that the forty-meter level was added. In 1923 much smaller numbers of catches were made and the interruptions of collecting were frequent and extensive. The ten-meter level was added to this series. In 1924 some collections were also taken at thirty, fifty, and sixty meters. No collecting was done in 1925 by boat. In 1926 five-meter intervals were added (see Introduction). The times of collecting were not identical in any two years and the periods of interruption were different. While any or all of the differences noted in this paragraph may have been immaterial, it is surely possible that each and all of them may have been important and that some of them may have occluded essential points in the records. This possibility is strikingly illustrated by the daily records of 1921 (Allen, 1923*a*, p. 75) in which there are several single days yielding large catches which might have been entirely missed if catches had been made on only two days of the week. This would probably have affected station 2 more than station 1 and it might have made production at the two stations appear to be nearly equal.

However, the clear preponderance of station 1 at all levels in 1926 largely offsets that possibility and it seems permissible to assume that the semiweekly collections of later years give fairly trustworthy indication of the gross features of distribution at the two stations. If this assumption be accepted it becomes evident that the two stations may differ widely in different years, not only in respect to the numbers produced at each but also in respect to the productivity of either as compared with the other. So far, no satisfactory explanation of these differences has been found.

Larger Numbers at Surface and Thirty-meter Levels

There has been strong indication in former years (Allen, 1923*b*, Dorman, 1927, Sleggs, 1927) that normal production in summer at both stations was probably greatest at twenty to forty meters below the surface. The 1926 catches bring these indications to the verge of proof (table 1). Indications have been equally strong that the surface level is normally second in productivity. Such conditions naturally suggest that thirty meters is approximately the level most generally optimum for a diatom population considerably different in com-

TABLE 3

Relative Abundance of Prominent Species in Five Seasons of Boat Work

In small squares, upper left to right is rank in 1921–1922–1923. Lower left to right is rank in 1924 and 1926.

Depth in meters	Names of prominent species																		
	Bacteriastrum elongatum Cl.	Chaetoceras compressum Laud.	Chaetoceras criophilum Castr.	Chaetoceras debile Cl.	Chaetoceras decipiens Cl	Chaetoceras neapolitanum Schr.	Chaetoceras scolopendra Cl.	Chaetoceras species	Dactuliosolen tenuis Cl..	Eucampia zoodiacus Ehr.	Hermiaulus hauckii Grun.	Nitzschia seriata Cl.	Rhizosolenia semispina Hens.	Skeletonema costatum (Grev.)	Thalassiosira subtilis (Ostf.)	Thalassiothrix acuta Karst.	Thalassiothrix frauenfeldii (Grun.)	Thalassiothrix longissima Cl. and Grun.	Thalassiothrix nitzschioides Grun.
Station 1																			
0		3	3 4	4	2 5			1 1 1				2 2				3		5	
		2						1 1			5	3	2				4		
20		1	5 3	3 3	5		1	2 2 2		4		1 1						4	
	5	1	3					2 2				4	1				3		
30	5 4		2					3 2	4			3	1				1		5
35	5 4	5	4					3 3	2			2	1				1		
		1	4 4	3				2 5	3			1 2			5				
40	5		2			4		3 3	4			2	1				1	5	
Station 2																			
0		2	4 4	4	2 3 3			1 1 5				2 1				5			
	2 5			3				1 1			4	4 2	5				3		
20		2	5 4		3			1 3		2 2		4 1 1	3	5		5			
		5						2	2	3		3	1				1		4
30	4		3				5	2 2	3			3	1				1	4	
35	4		3			5		2 2				3	1				1	4	3
		2	4 3	5	5			3		1		2 1				4			
40	5		2					2 3		3		5 2	1				1	4	4

position from that at the surface. It also leads to the inference that the adaptation of marine pelagic diatoms is closely related to normal environmental conditions in these two zones.

A general survey of the records (imperfect) for the five seasons does not invalidate such suppositions but it does show positively (table 3) that the relationships are neither simple nor clear. Later discussion of individual species will contribute somewhat toward clarification. On the general showing most of the prominent species—those in the highest five for a series of catches—are well distributed through a number of levels, appearing prominent in many cases at both surface and thirty-meter levels. This feature of distribution suggests a warning that leadership in production or abundance of production does not necessarily indicate a zone of optimum conditions in respect to physical and chemical factors. Any one of the species participating in leadership, through this wide range of difference in such factors as heat and light, might show a narrow field of optimum if relieved from the pressure of biological influences. Competition with others may cause a species to exhibit an apparent optimum at a level considerably removed from the one which would be the real optimum if biological factors were removed or rendered impotent. For example, *Chaetoceras* sp. (mainly an assemblage of small and poorly marked forms) may lead at the surface layer because it can tolerate an intensity of light too great for more vigorous competitors of lower levels, and not because it would thrive best at the surface if given conditions of pure culture.

However, table 3 shows definitely that a few species tended to prominence at both stations in the five seasons, that two or three others are sporadic but robust in appearance, and that some tend to prominence at the lower levels. These points will be discussed more fully under the species headings.

So far as 1926 is concerned, it is evident that *Thalassiothrix frauenfeldii* (Grun.) found most favorable conditions near the thirty-meter level while *Chaetoceras* sp. had the advantage at the surface. Since there is no question that these forms took the lead in the two levels it is possible to regard their distribution as indicative of the operation of influences differing materially in the two zones. As a matter of fact, it is fairly well known that both the surface and thirty-meter levels are regions of sharp transition in some physical and chemical factors of the environment. At the surface there is the greatest possible amount of radiant energy and of derivatives from the atmosphere, in all of which (but in light especially) there is rapid change in the first few meters. Near the thirty-meter level there are sharp changes in hydrogen ion concentration, nitrates, and phosphates.

This is well indicated by records for the boat work of 1926 which have not yet been published. These records show sharp increases in these three factors in the zone from thirty to forty meters, mostly near thirty meters. In some cases, notably rapid reduction of temperature also occurred in this zone. It seems, therefore, that under normal conditions in the La Jolla locality there is a relatively stable productive zone between the surface and thirty meters, tending to support at its two margins somewhat different populations, both of which are largely composed of species having a wide range of tolerance which permits their admixture at intermediate levels to a considerable extent. It also permits existence of some of them at considerably greater depths, at least in the summer season. This downward extension may be due to the deeper penetration of light because the rays of the sun are more nearly vertical in midsummer. The problem of leadership in production at the surface and at the thirty-meter levels would be easy to solve if we found highly productive species confined to those levels; it is a difficult problem because highly productive species range through wide differences of levels and their accompanying conditions.

In one of his latest papers as well as in some of much earlier date, Gran (1927) emphasizes the importance of considering the contribution made by the sinking of decadent or moribund individuals originally resident in higher levels. Although, as he says (1915), such emphasis originated with American students of fresh-water conditions nearly fifty years ago, we have not discussed it in Scripps Institution papers heretofore because the influence of such sinking in most of our material has not been evident or clear. In fact, I only mention it now because I am sure that Gran is right in demanding that the point be given careful consideration. In 1926 the material from stations 1 and 2 was studied one or two days after taking, but there was not sufficient indication of decadence to attract attention in components of catches at lower levels. Furthermore, if sinking played a very important part in the showing at lower levels in June and July the catches at sixty meters should have run much larger than they did.

Constancy at Surface and Forty-meter Levels

The detailed reports for 1926 show plainly that through June and July the greatest constancy of production was at the forty-meter level and that the surface level was second in this respect. This is shown less distinctly by figure 1 and still less distinctly by table 1. In preceding years too few levels were sampled to permit instructive comparison. If 1926 represents normal conditions in this respect, the

greater constancy in these two levels can be partly explained by shifting conditions which supplied favorable environment to a variety of forms without giving quite enough stability to support their maxima in the larger number of cases.

Time of Productivity

As indicated by figure 2 the peak of production at both stations was reached before the middle of July, probably in late June. In the latter part of July distinct evidences of decline are shown by the graph. This showing is in substantial agreement with that of preceding seasons (see Allen, 1923*a*, *b*, Dorman, 1927, and Sleggs, 1927) wherein the distinct decline began about July 8 in 1921 and July 15 in 1924, and was possibly beginning on June 20 in 1922 and July 15 in 1923. Although the work was suspended in 1922 and 1923 before the middle of July, general appearances of those years support the evidence of the other three that production tends to decline at both stations after the middle of July.

Prominent Species

Under this heading I have selected nine species from each station. This selection is not made entirely on the basis of numerical prominence although all of those selected show (at some level) numerical prominence within the first ten. All of those selected are to be found in the list of prominent species for the five seasons given in table 3. The fact that the lists from the two stations are identical probably has some significance as an indication that production at these offshore localities runs, in general, a parallel course. By reference to table 3 it may be noted that the most productive species for 1924, *Rhizosolenia semispina* Hensen, is missing from these lists. Its place in numerical (and, incidentally, volumetric) dominance in 1926 is taken by *Thalassiothrix frauenfeldii* (Grun.).

Bacteriastrum elongatum Cleve

As indicated by table 4 this species was not recorded for 1926 above twenty meters. It was considerably more abundant at station 1 than at station 2 and it was missing in many catches at the different levels at both stations. It had not been found in many catches of preceding years although its distribution in 1924 resembled that of 1926. In La Jolla localities it seems to belong to habitats in moderate depths offshore.

TABLE 4

NUMBERS PER LITER OF CELLS OF *Bacteriastrum elongatum* CL. IN SAMPLES OF SEA WATER AT DIFFERENT DEPTHS IN SUMMER, 1926, NEAR LA JOLLA

	Station 1. 16 catches				Station 2. 16 catches			
Depth meters	Total 16 catches	Average to catch	Largest catch	Number catches zero*	Total 16 catches	Average to catch	Largest catch	Number catches zero*
0	.....	.....	.....	16	.....	.....	.....	16
5	.....	.....	.....	16	.....	.....	.....	16
10	.....	.....	.....	16	.....	.....	.....	16
15	.....	.....	.....	16	.....	.....	.....	16
20	2,020	126	1,188	11	4,480	280	2,080	13
25	20,310	1,269	15,200	10	4,336	271	2,640	9
30	26,151	1,634	11,400	8	13,196	825	8,400	10
35	25,776	1,611	14,364	7	3,440	215	2,560	13
40	12,370	773	3,164	8	6,664	417	4,592	10
50	9,160	571	3,640	9	2,836	177	1,100	10
60	10,076	629	6,328	10	1,100	69	480	11

* In this and similar tables following, the column headed "number catches zero" means number of catches yielding none.

Chaetoceras compressum Lauder

This species is usually extremely difficult to distinguish from several other small species. It is highly variable in general appearance and in dimensions. The most prominent characteristic, which consists of the enlarged, flexuose setae, distributed at irregular intervals in a typical filament, are often missing, even in rather long chains. The numbers given in the accompanying table are therefore only rough approximations. For most catches at most levels none were recorded and the distribution appears to be somewhat erratic.

TABLE 5

NUMBERS PER LITER OF CELLS OF *Chaetoceras compressum* LAUDER IN SAMPLES OF SEA WATER AT DIFFERENT DEPTHS IN SUMMER, 1926, NEAR LA JOLLA

	Station 1. 16 catches				Station 2. 16 catches			
Depth meters	Total 16 catches	Average to catch	Largest catch	Number catches zero	Total 16 catches	Average to catch	Largest catch	Number catches zero
0	30,345	1,897	22,755	12	4,824	301	1,628	11
5	9,408	588	4,576	11	.....	.....	.....	16
10	31,525	1,727	27,639	12	1,200	75	1,200	14
15	25,608	1,600	14,640	9	7,000	437	3,840	10
20	37,493	2,343	23,643	9	5,360	335	3,920	13
25	16,788	1,049	8,560	11	3,506	219	1,280	11
30	13,814	863	4,400	10	7,252	453	6,960	13
35	16,556	1,035	12,236	12	2,240	140	2,240	15
40	6,168	385	2,400	10	1,920	120	1,280	14
50	3,602	225	3,040	13	.....	.....	.....	16
60	1,518	95	1,232	14	.....	.....	.....	16

The indication of the 1926 material is that the species thrives best above the twenty-meter level and at a considerable distance offshore. It is so frequently found in collections from widely different localities that it must be considered a species having much greater possibilities of importance than those indicated here.

Chaetoceras neapolitanum Schroeder

This species was rare prior to 1926, although a few specimens had been found from time to time in various localities. Its 1926 distribution was confined strictly to the lower levels, there being no record above twenty-five meters at either station. Its representation was somewhat irregular, even in the lower levels, but it reached a productivity of 36,800 cells to the liter at thirty-five meters at station 1 on August 31. The numbers at station 2 were usually smaller than those at station 1. So far it appears to be an oceanic species thriving best at lower levels in the La Jolla region.

Chaetoceras scolopendra Cleve

In spite of its usually very small size this species can be identified in most cases by its general appearance. It is very commonly found and it is sometimes an important component of the inshore plankton (Allen, 1927*b*). For that reason its presence in these catches, at lower levels only (none above twenty meters), seems rather strange. It did not appear at either station in very large numbers, the largest being 4,080 cells to the liter at station 1, twenty-five meters.

Chaetoceras sp.

In the main this is an assemblage of very small, poorly marked forms lacking features sufficiently distinct for the identification of species. It frequently includes more or less atypical specimens in a mixed population exhibiting a large proportion of identifiable individuals. In spite of its unsatisfactory limits the assemblage has considerable importance and its distribution is not without interest.

At both stations its maximum total for any level in the series of catches was reached at thirty meters, although the largest single catch at station 1 was made at twenty-five meters. Its numerical dominance tends to be most pronounced in periods unfavorable to the clearly recognizable common species. This fact gives good ground for supposing that unfavorable conditions cause development of a larger percentage of atypical, abnormal, and imperfectly formed individuals of

many species which necessarily are enumerated together under a catch-all designation. It is also possible that the lack of differentiating characteristics indicates organisms with great powers of endurance coupled with slow powers of response to favorable conditions. They may be hard to kill off but they may be just as hard to stimulate to robust development or abundant production.

Whether we take such suppositions lightly or seriously, we cannot ignore the fact that small and feeble forms of *Chaetoceras* are widely distributed geographically and bathymetrically, that they frequently outnumber other diatoms in lightly productive series of catches, and that they often take a conspicuous part in heavy production. These

TABLE 6

NUMBERS PER LITER OF CELLS OF *Chaetoceras* SP. IN SAMPLES OF SEA WATER AT DIFFERENT DEPTHS IN SUMMER, 1926, NEAR LA JOLLA

	Station 1. 16 catches				Station 2. 16 catches			
Depth meters	Total 16 catches	Average to catch	Largest catch	Number catches zero	Total 16 catches	Average to catch	Largest catch	Number catches zero
0	33,747	2,109	23,559	5	24,336	1,521	12,408	4
5	9,384	586	3,120	9	12,376	774	8,560	7
10	34,056	2,128	20,194	7	15,360	960	1,680	8
15	20,254	1,266	10,080	9	15,320	950	8,320	8
20	19,370	1,211	6,080	6	18,708	1,169	6,480	7
25	51,632	3,227	32,760	5	19,156	1,197	5,120	13
30	63,297	3,956	22,280	5	43,150	2,690	20,400	2
35	33,610	2,101	8,778	5	10,192	637	3,440	5
40	33,072	2,067	8,480	3	11,970	748	3,200	5
50	19,966	1,248	2,904	3	6,238	389	2,684	6
60	16,126	1,008	4,180	6	1,498	94	528	11

points are well shown by table 3 where the group led in numbers at the surface level at the two stations in the five seasons and was second or third in most of the cases at other levels. According to the indications of the 1926 series, production is best at the thirty-meter level and the ten-mile station.

Hemiaulus hauckii Grunow

Hemiaulus was one of the genera peculiar to 1926 in the San Diego region. Not only was it rare at stations 1 and 2 in preceding years but it was also rare in other series of catches. As will be shown later it was conspicuous in surface catches in the general region of San Nicholas and Santa Catalina islands as early as March. Casual inspection of catches from inshore stations also indicates a general and fairly persistent distribution in the southern California region.

As shown by table 7 the numbers were not very large and the number of catches in which specimens were found was small, even at the most favorable levels. The importance of the group in this discussion depends largely on the peculiarity of its appearance in 1926. However, the fact deserves notice that, more than any other group, it seems to be sharply limited to the upper ten meters.

Species identification was not fully satisfactory because of either a wide range of variability or the presence of two or more species. Some of the differences in shape and size of the cells were remarkable. The presence of many shapes and sizes intermediate to the extremes

TABLE 7

NUMBERS PER LITER OF CELLS OF *Hemiaulus hauckii* GRUN. IN SAMPLES OF SEA WATER AT DIFFERENT DEPTHS IN SUMMER, 1926, NEAR LA JOLLA

	Station 1. 16 catches				Station 2. 16 catches			
Depth meters	Total 16 catches	Average to catch	Largest catch	Number catches zero	Total 16 catches	Average to catch	Largest catch	Number catches zero
0	4,816	301	1,880	7	7,264	454	4,752	11
5	4,400	275	2,960	11	6,080	380	3,040	12
10	4,480	280	1,600	10	5,200	325	1,680	11
15	1,760	110	800	13	960	60	720	14
20	1,200	75	560	13	800	50	640	14
25	880	55	560	12	0	0	0	16
30	320	20	320	15	248	15	160	14
35	266	17	266	15	0	0	0	16
40	400	25	400	15	0	0	0	16
50	80	5	80	15	0	0	0	16
60	0	0	0	16	0	0	0	16

made it seem advisable to include all under the name of *H. hauckii* Grun., especially since it was not clear that they more closely resembled another species. Available evidence indicates a probability that the group does best near the surface and near land, but that in most years it is not able to reach notable productivity in the southern California territory.

Nitzschia seriata Cleve

This species is so frequently found and so often appears in moderate numbers or in great abundance that it is to be reckoned one of the most important forms in the east Pacific. It evidently responds quickly to favorable conditions for its numbers often show remarkable increase in a few days without indication of being swept in to the collecting station by currents. In its typical form it is easy to identify, but it has a wide range of variability which is sometimes confusing.

In some catches nearly all specimens of a large population may be atypical. Most often there are many intermediate stages between small, thin cells, and large, strongly spindle-shaped cells. Although there is reason for thinking that two or more species are sometimes included under this species, efforts to separate them have not yet proved to be worth while.

In three out of the five seasons of work at stations 1 and 2 *Nitzschia seriata* Cl. has been very prominent at several different levels (table 3). Relative to other species, its productivity in preceding years has been

TABLE 8

NUMBERS PER LITER OF CELLS OF *Nitzschia seriata* CLEVE IN SAMPLES OF SEA WATER AT DIFFERENT DEPTHS IN SUMMER, 1926, NEAR LA JOLLA

	Station 1. 16 catches				Station 2. 16 catches			
Depth meters	Total 16 catches	Average to catch	Largest catch	Number catches zero	Total 16 catches	Average to catch	Largest catch	Number catches zero
0	3,662	229	1,276	6	10,284	643	5,068	4
5	2,300	144	880	9	4,884	305	2,156	5
10	4,124	257	1,320	11	3,588	224	2,860	10
15	1,286	80	560	11	3,008	188	1,188	9
20	4,916	307	1,672	8	7,688	480	4,080	8
25	11,570	723	3,784	7	11,608	725	5,040	6
30	42,898	2,681	11,800	4	32,220	2,014	14,800	3
35	30,890	1,931	7,896	2	9,400	671	3,040	6
40	26,939	1,684	8,547	1	14,680	917	5,432	4
50	16,374	1,023	6,104	3	5,352	334	1,680	6
60	11,198	700	4,088	4	1,938	121	640	8

best at or near the surface. However, this may be partly due to lack of sufficient numbers of catches at lower levels. There is therefore no evidence directly contradictory to that exhibited in table 8 where the production at five levels below twenty meters is definitely greater than it is at levels above that point, although none of the catches in 1926 were very large. All things considered, it is not improbable that its optimum is at a depth of about thirty meters and away from shore, as suggested by table 8.

Thalassiothrix frauenfeldii (Grunow)

The genus *Thalassiothrix* is represented in the La Jolla region with fair continuity, especially by the three larger species, *T. acuta* Karst., *T. frauenfeldii* (Grun.), and *T. longissima* Cl. and Grun. Table 3 gives the main features of distribution observed in the five seasons of work at stations 1 and 2. Up to 1926, *T. frauenfeldii* had been the rarest of the four species but it then came into a prominence

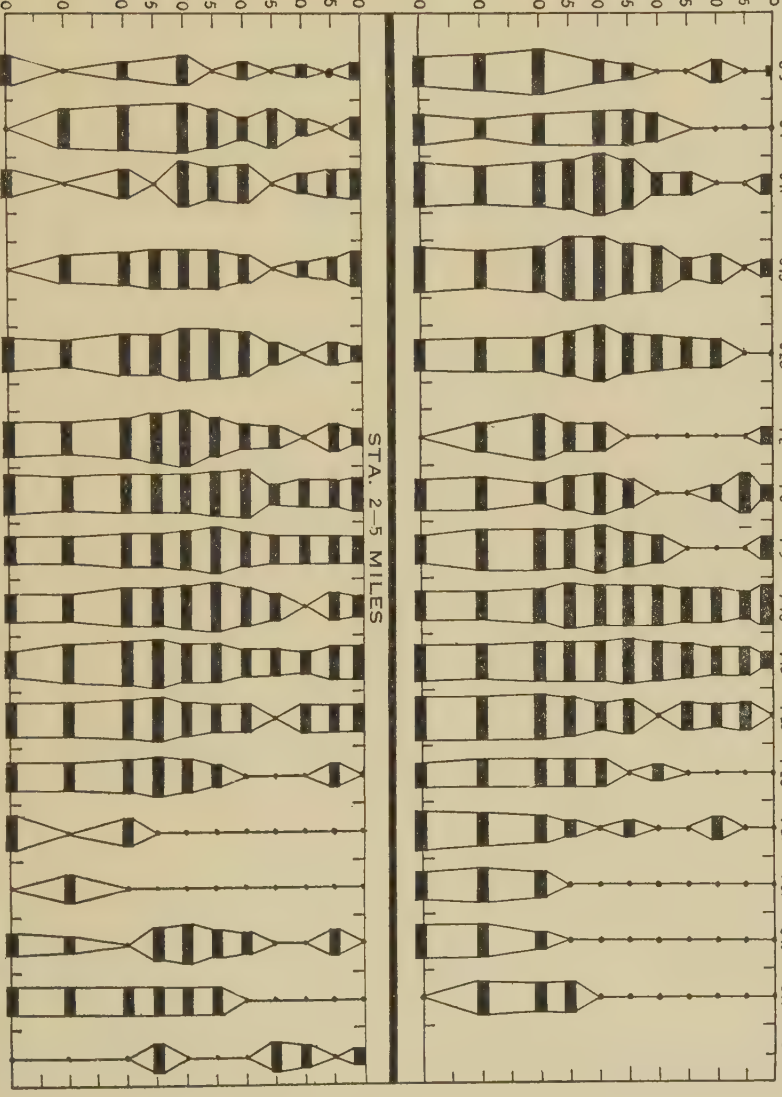

Fig. 3. Surface and subsurface distribution of *Thalassiothrix frauenfeldii* (Grun.) at Stations 1 and 2. Cross-bars represent logarithms of numbers per liter at each level. Numerals indicate dates, and depths in meters.

not before approached by the whole genus. Throughout most of the series of collections at the two stations its characters were well marked and quite typical, but in a considerable number of catches the cells ranged toward *T. nitzschioides* Grun. in shape and size, and even the colony formation was poorly defined. The amount of error due to these aberrations is probably not great, certainly not enough to affect the showing of distribution in the accompanying graph (fig. 3).

The most important feature of this graph is its indication of scanty production at or near the surface. Next most important is its indication of constancy of production through June and July at the thirty- and forty-meter levels at both stations. Out of the thirty-three surface catches, fourteen yielded none of this species and twelve others yielded less than one hundred cells to the liter. Both of these features are very strongly indicative that *T. frauenfeldii* is distinctly favored during summer by conditions at a considerable distance below the surface. Even the fifty- and sixty-meter levels were more strongly and continuously productive than the surface.

The smaller catches of early June and late July (fig. 3) suggest a probability that the seasonal range of the species is limited. Although not clearly shown by figure 3 (on account of the small scale to which the graph is drawn), the total production at station 1 was considerably in excess of that at station 2. On the other hand, production was better sustained at a larger number of levels at station 2.

On the general showing of the two stations it appears that this species finds most favorable conditions for development in levels between twenty and forty meters in offshore waters. The cells are large and the mass production runs relatively high as compared with similar numbers of cells of many other prominent diatoms.

Thalassiothrix nitzschioides Grunow

In many catches this species was not well defined. Large specimens might be confused to some extent with small specimens of *T. frauenfeldii* (Grun.) and small specimens might be confused with *Grammatophora marina* (Lyngb.) under the low magnification used in counting. However, in most of the catches below twenty-five meters at both stations considerable numbers were found which were easily recognizable.

In other series it has often been found at surface levels, sometimes in larger numbers than those observed here, but in lack of subsurface observations on such occasions it is impossible to say that the maximum production may not have been at a lower level. As indicated

by table 3 the species had notable relative productivity at similar levels in 1924. On the showings of 1924 and 1926 one might conclude that this species is more abundant at lower levels but there is not much difference in its distribution at the two stations (table 9).

PHYSICAL AND CHEMICAL CONDITIONS

Hydrographic and chemical observations ran two or three times per week concurrently with the plankton catches but on different days. Both McEwen and Moberg have expressed the opinion that the records for the missing days can be obtained by interpolation to a degree of accuracy within the range of the unavoidable errors of sampling.

TABLE 9

NUMBERS PER LITER OF CELLS OF *Thalassiothrix nitzschioides* (GRUN.) IN SAMPLES OF SEA WATER AT DIFFERENT DEPTHS IN SUMMER, 1926, NEAR LA JOLLA

	Station 1. 16 catches				Station 2. 16 catches			
Depth meters	Total 16 catches	Average to catch	Largest catch	Number catches zero	Total 16 catches	Average to catch	Largest catch	Number catches zero
0	0	0	0	16	0	0	0	16
5	0	0	0	16	0	0	0	16
10	0	0	0	16	0	0	0	16
15	0	0	0	16	0	0	0	16
20	0	0	0	16	5,880	367	2,600	12
25	0	0	0	16	9,488	593	2,880	7
30	17,036	1,065	3,360	4	12,512	788	4,720	7
35	11,190	700	2,640	4	5,360	335	3,520	11
40	9,804	618	2,200	7	7,422	464	2,640	7
50	4,568	285	1,364	8	3,320	207	1,520	9
60	3,304	207	1,188	8	772	48	560	12

Since the tables and graphs on the preceding pages show very clearly that the main constituents of the phytoplankton have not only a range of tolerance but a considerable productivity through levels involving greater changes in temperature and other physical factors than is shown from day to day at any level, it appears unpromising to attempt to trace correlations between these factors and productivity before a vast amount of statistical material has been accumulated. Examination of graphs and records available does not suggest recognizable correlations between productivity and single factors of environmental conditions. In fact it is not probable that the moderate or small numbers in the catches for 1926 would tend to bring specific correlations into view. Physical and chemical factors are not being ignored in this series but the evidence of their influence is not sufficiently clear to warrant extensive discussion.

Summary

1. It is very important to accumulate observations from subsurface levels at intervals not greater than five meters, at least down to the forty-meter level, preferably to sixty meters.

2. Complete subsurface series taken on two days of the week at offshore stations through the summer season probably give a fairly dependable view of the facts of distribution of diatoms and dinoflagellates.

3. Evidence of five seasons of boat work indicates that summer productivity of diatoms is best at a considerable distance below the surface. But, since much of this evidence is based on the showing of inconstant species, it may yet appear that maximum production is to be found at different levels according to the numerical dominance of different species.

4. Five seasons of boat work at stations 1 and 2 indicate that less than a score of species of diatoms have taken parts at all prominent in summer production.

5. The five seasons have also shown that rare or inconsequential species may take the lead in production in some single year. It also appears that when a species comes into unusual prominence its influence may be found over a territorial range of scores of miles.

6. The series of catches for the five seasons agree in showing that most of the prominent species are distributed through several other levels both above and below the one supporting their maxima.

7. The wide range of tolerance shown by individual species of diatoms, as well as by the diatoms as a whole, makes it necessary to be cautious in attempting to trace correlations between productivity and ordinary changes in physical and chemical conditions.

8. Collections at these stations indicate that offshore production of dinoflagellates of the plankton type is usually best at or near the surface of the sea in the summer season.

THE AUGUST CRUISE

Territory Covered

From August 17 to August 27 inclusive, the "Thaddeus" was used in making a collecting and observational cruise (mainly in the channel regions) between La Jolla, near the southeastern end of the Gulf of Santa Catalina, and Point Conception, at the western end of the northerly shore line of the Santa Barbara Channel (fig. 1). Since there was considerable difference in the details of plankton collecting

in the different sections of this territory, in addition to certain geographic differences which require particular attention, it has been found necessary to divide the territory into six sections for purposes of discussion. These divisions have a natural basis in the geographical configuration of the territory, but the limits assumed for purposes of discussion are somewhat arbitrary.

Section 1 was on a direct line from the Scripps Institution to Point Fermin. Section 2 was mainly confined to a line connecting the headlands of Santa Monica Bay and to seaward stations within limits parallel to that line. Section 3 comprised stations within five miles of Point Hueneme pier, and those twenty miles to seaward in a southerly direction and coastwise nearly to Point Dume. Section 4 included stations near Santa Barbara and in Santa Barbara Channel, southeast nearly to Point Hueneme and southwest nearly to Santa Rosa Island. Section 5 included stations near Santa Rosa Island, mostly in Santa Cruz Channel or near its northern entrance. Section 6 comprised a few stations on a line from Santa Rosa Island to Point Conception. These sections are indicated by their corresponding numerals on the general map (fig. 1).

On this cruise a total of one hundred and thirty-five stations were occupied for collecting plankton by methods mentioned in the introduction to this paper. At nine of these stations sixty subsurface catches were taken with the Allen closing bucket. Combined with the number of surface catches from all of the stations there was a total of one hundred and ninety-five catches for the cruise. One hundred and seventy-seven of these were taken north of Point Fermin where topographical and hydrographical conditions are considerably different from those found in the La Jolla region. The intervals between collecting stations were variable as regards both time and space. To a large extent collections were increased and decreased in frequency according to surmises of the scientific staff as to greater or less probability of getting instructive material. Aside from this the location of a collecting station was determined by convenience and the probability that the spot was fairly representative of conditions in its vicinity.

1. Gulf of Santa Catalina Section

Only surface collections were taken in this section, eighteen in all. Most of them were obtained at points about ten miles from shore between Point La Jolla and Point Fermin. None of them were large. The only catches which exceeded one thousand cells to the liter were in the immediate vicinity of San Pedro Harbor. There the largest

catch of diatoms was 3,160 cells to the liter, and the largest catch of dinoflagellates was 1,480 cells to the liter. These small numbers are in agreement with former records of surface catches in the Gulf of Santa Catalina in August. Therefore it is probably safe to assume that the usual production of these organisms at that level is light in late summer in the territory between San Diego and San Pedro.

A fairly large number of species of both diatoms and dinoflagellates (nineteen of each) was represented in the series of catches, but most of them were found only in catches near the northern limits of the section. Three kinds of diatoms yielded numbers sufficiently large (as compared with others) to attract attention. These were, in order of total numbers recorded, *Hemiaulus hauckii* Grun., *Chaetoceras* sp., and *Asterionella japonica* Cl., the first and third being species rarely so prominent even in small populations.

The dinflagellates were so few and so scattered in distribution that scarcely any species deserves special mention, although *Peridinium divergens* Ehr., exhibited a slight lead.

2. Santa Monica Bay Section

On the outbound trip, August 18, eight surface catches were taken on a line from Point Vincente to Point Dume. On the return trip a week later, August 26, six surface catches were made a little farther inshore than this line. Additionally, on the return trip near and to southwest of Point Dume six stations were occupied, at three of which subsurface samples were taken.

General Productivity at the Surface

General production at the surface was slightly better in case of diatoms than in the first section, slightly poorer in case of dinoflagellates. Two catches of diatoms near Point Vincente were notably better, one reaching a total of one hundred thousand cells to the liter, the other nearly fifty thousand. Lacking evidence beyond that for the single day, it can only be conjectured that the larger catches near Point Vincente may indicate a superior localized production due to influence of the Los Angeles sewage draining into Santa Monica Bay a little to the northward.

Species Represented

The list of species of diatoms was slightly larger, twenty-five, than that for section 1, while that for the dinoflagellates, nineteen, remained the same.

The most prominent diatom form was recorded as *Leptocylindrus danicus* Cl., but there was some confusion of it with another form

appearing in chains of cylindrical cells which was recorded as *Detonula schroederi* (P. Bergon). Distinctions recognizable with higher magnifications often disappeared under counting conditions. *Thalassiothrix acuta* Karst. and *Chaetoceras* sp. were the only other forms of noticeable prominence.

Peridinum divergens Ehr. with a very light representation was the leading dinoflagellate.

GENERAL PRODUCTIVITY BELOW THE SURFACE

Subsurface catches in this section were taken at three stations: D136 about thirteen miles southwest of Point Dume, D138 about five miles southwest, and D142 about three miles west of the same point. These catches were made on August 25, 26, and 27, respectively.

Fig. 4. Surface and subsurface catches on August cruise. Cross-bars represent logarithms of numbers per liter. Numerals indicate depths, letters and numerals indicate stations.

At all three stations the catches below the surface yielded few species of either diatoms or dinoflagellates and none of the numbers were very large, the maximum being 48,920 cells to the liter for total diatoms at forty meters, station D138. The general relationship of the totals of diatoms at different levels is roughly indicated by the accompanying graph (fig. 4, D136–D142).

THE INDIVIDUAL STATIONS

At D136 the catches were all extremely light. The largest (960 cells to the liter) was at the ten-meter level. It was composed mostly of *Chaetoceras* sp.

Dinoflagellates were barely represented by a few specimens of *Dinophysis caudata* Kent.

At D138 the numbers of diatoms were notably larger, but there was little difference in the numbers of dinoflagellates. Most of the increase in representation of diatoms was below the twenty-meter level (maximum at forty meters, fig. 4, D138) where *Thalassiothrix frauenfeldii* (Grun.) held the lead, with *Chaetoceras* sp., *C. scolopendra* (Cl.), *Thalassiothrix nitzschioides* Grun., and *Nitzschia seriata* Cl. in some prominence according to the order named.

At D142 dinoflagellates were very poorly represented and all of the catches of diatoms were small, especially above thirty meters (fig 4, D142). The maximum, 10,000 cells to the liter, was at fifty meters, and *Thalassiothrix frauenfeldii* (Grun.) contributed about a third of this. *Chaetoceras* sp., *C. scolopendra* (Cl.), and *Nitzschia seriata* Cl. were again in some prominence.

In composition and in distribution of numbers the subsurface catches in this section showed a considerable resemblance to those of June and July at stations 1 and 2 (figs. 2, 3). This is especially notable in the case of *Thalassiothrix frauenfeldii* (Grun.), the predominant form in the La Jolla series.

3. Point Hueneme Section

Twenty-two subsurface catches were taken in this section, mostly near Point Hueneme, or on a line to station D42, twenty-one miles southwest of that point. Seventeen were taken on the outward trip and five on the return, less than a week later. Subsurface catches were taken only at D33 and D42, respectively two and twenty-one miles from Point Hueneme pier.

General productivity at the surface

Diatoms were well represented in this section, but not in large numbers, the maximum being about fifty thousand cells to the liter at D29, a station much nearer to Point Dume than to Point Hueneme. The representation of dinoflagellates was poor in total numbers, although station D47, two miles from Point Hueneme, yielded over eight hundred cells to the liter.

Species Represented

Thirty-three species of diatoms were noted, the most prominent being *Leptocylindrus danicus* Cl., *Chaetoceras* sp., *Thalassiothrix acuta* Karst., *Nitzschia seriata* Cl., and *Thalassiothrix frauenfeldii* (Grun.). *Leptocylindrus danicus* Cl. was much in excess of all the other species at the stations nearer Point Dume and Point Hueneme.

It was entirely missing in the surface catches of several stations a little farther from shore. The other leading species were more evenly distributed at the different stations in the section.

Except for *Peridinium divergens* Ehr., the nineteen species of dinoflagellates recorded for this section were represented by very few specimens in scattering catches. Even this species was missing in several catches and it reached a production of only 500 cells to the liter at station D47, near Point Hueneme.

GENERAL PRODUCTIVITY BELOW THE SURFACE

Although one of the two series of subsurface catches was nearly twenty miles farther from shore than the other (D33, two miles, D42, twenty-one miles) they showed a considerable resemblance in distribution. At both stations dinoflagellates were very few at all levels and diatoms were few above twenty meters (fig. 4). The only prominent difference was that the deep-water station had light production down to the thirty-meter level, where the series for the shoal-water station stopped. Since the limited depth is fully sufficient to account for this difference, there is no need to attempt any other explanation.

Not many species of diatoms were recorded at either station, sixteen at D33, thirteen at D42.

Species of dinoflagellates were not separated.

The Individual Stations

At station D33 several species of diatoms had consistent representation at the lower levels, reaching their greatest combined total (34,440 cells to the liter) at twenty-five meters. *Thalassiothrix frauenfeldii* (Grun.) appeared in considerably larger numbers than any other species at the twenty-five and thirty-meter levels, with a maximum of 16,000 cells to the liter at thirty meters. The other species appearing in some prominence at levels from fifteen to thirty meters were *Chaetoceras* sp., *C. scolopendra* (Cl.), and *Nitzschia seriata* Cl.

At station D42 the same species as those just mentioned for D33 had similar relationships, except that the maximum total (34,240 cells to the liter) was at forty meters (fig. 4) and that others of the larger catches were at similarly lower levels than at D33. For example, the maximum (10,000 cells to the liter) for *Thalassiothrix frauenfeldii* (Grun.) was at forty meters, ten meters lower.

Such close resemblances at the two stations suggest a probability that conditions of subsurface production (irrespective of configuration of the bottom) were much alike over a large area in this section at that time.

4. Santa Barbara Section

Surface catches only were taken at all of the fourteen stations in this section, which comprised the Santa Barbara Channel between Santa Cruz Island and the mainland. Eight stations were occupied on August 20, one on August 24, and five on August 25.

General productivity at the surface

Representation of the diatoms was fairly good, of dinoflagellates very poor. The only catch of dinoflagellates greater than five hundred cells to the liter was taken near Santa Barbara pier on August 20. The largest catch of diatoms (161,720 cells to the liter) was taken on the return trip about midway between Santa Rosa Island and Santa Barbara pier. Two other catches on the following day, respectively one and six miles southeast of Santa Barbara, yielded more than sixty thousand cells to the liter. All other catches were comparatively small.

Species Represented

An unusually large number of species, forty-four, was recorded for diatoms in this section. Most of these were noted only a few times and in small numbers. Twelve belonged to the genus *Chaetoceras*. *Rhizosolenia* was represented by eight species.

Chaetoceras sp. was the leading form. It had a maximum of 67,000 cells to the liter at the station midway between Santa Rosa Island and Santa Barbara pier. *Nitzschia seriata* Cl. and *Chaetoceras scolopendra* Cl. were also prominent and showed largest numbers in the same locality. In smaller numbers, but next in prominence to these, were *Thalassiothrix frauenfeldii* (Grun.) and *Rhizosolenia setigera* Btw. The evidence in this section indicated more favorable conditions for production at a considerable distance (about eighteen miles) from shore.

5. Santa Rosa Island Section

Forty-nine surface catches were taken in this section, thirty-six on the outgoing trip and thirteen on the return a day later. All but one of these catches were made at distances of less than ten miles from Santa Rosa Island pier, located near the northeast corner of the island somewhat below the entrance to Santa Cruz Channel which separates Santa Rosa and Santa Cruz islands (figs. 1, 5).

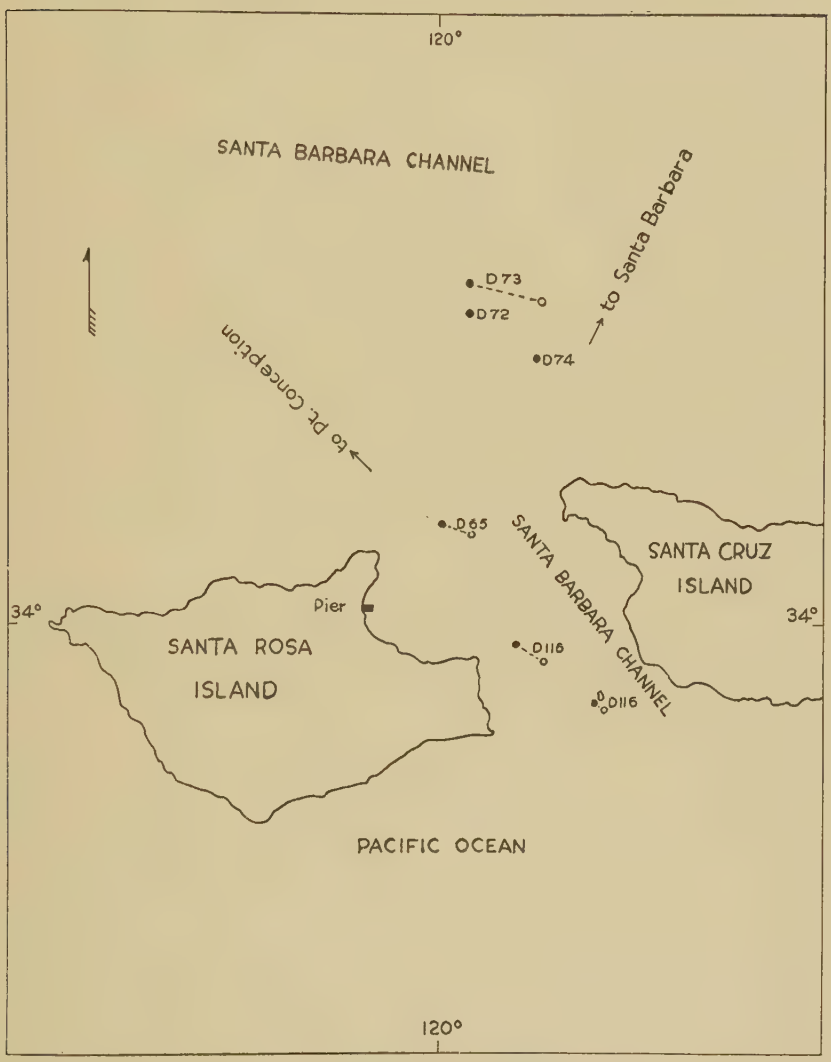

Fig. 5. Map of Santa Rosa Island section adapted from U. S. Coast and Geodetic Survey Chart 5202

GENERAL PRODUCTIVITY AT THE SURFACE

The yield of diatoms was distinctly greater at the surface than was found in any other section, only three catches out of the forty-nine showing a total less than twelve thousand cells to the liter. In fact, the yield of several different species was consistently greater than the totals in other sections. No such difference appeared in the case of dinoflagellates, which were few, as elsewhere.

Two of the poorly productive stations were about ten miles from Santa Rosa Island pier, toward the middle of Santa Barbara Channel. The other one was near the middle of Santa Cruz Channel at its southeastern end.

The surface yield at one station was about one million and seven hundred thousand cells to the liter, and two others yielded more than eight hundred thousand. The largest yield was at D57, nearly four miles northeast of Santa Rosa Island pier, and near the middle of the north end of Santa Cruz Channel. The next was at D77 nearly three miles farther out and near the eastern side of the north end of Santa Cruz Channel. The third was at D81, a little less than three miles from the pier and distinctly inside of Santa Cruz Channel, to the west of its middle. Surface temperatures at these stations were very low for August, the highest of the three being 16.3° C.

Sixteen of the catches yielding smaller totals were greater than five hundred thousand cells to the liter. Most of the others showed more than two hundred thousand diatom cells. It is evident therefore that surface production was probably very good over an area of about one hundred square miles. Surface temperatures at all of these stations were similar to those at the three stations giving the largest yields, and it is apparent that this is a region favorable to maintenance of production at a season found to be poor in other localities.

Species Represented

Fifty-five species of diatoms were noted, more than ten of which made important contributions in production. Five forms, however, were so distinctly superior in this respect that the others need have no special discussion.

The catchall group, *Chaetoceras* sp., was far in the lead. In only two catches did it fall below one thousand cells to the liter and its largest yield was nearly four hundred thousand.

Chaetoceras scolopendra (Cl.) was second in prominence. It had a minimum of zero twice, but it reached a maximum of more than eight hundred thousand cells to the liter in one catch.

Thalassiothrix frauenfeldii (Grun.) was third in prominence. It had a minimum of eight hundred cells to the liter and its maximum was a little less than two hundred thousand. Its cells were considerably larger than those of the Chaetoceras species, however, and there is no doubt that it held the lead in mass production.

Nitzschia seriata Cl. was fourth in numerical prominence. It had a maximum above one hundred and sixty thousand. It was more evenly distributed through the surface catches of this section than most other species.

The fifth in prominence was *Chaetoceras debile* Cl. It had one minimum of zero and its maximum was over one hundred thousand cells to the liter. It was well represented in most catches.

Other species showing considerable prominence were *Chaetoceras compressum* (Laud.), *C. decipiens* Cl., *C. sociale* Laud., *Lauderia borealis* Gran., and *Skeletonema costatum* (Grev.).

Peridinium divergens Ehr. was noted more frequently than any other dinoflagellate, but its numbers were very small, the maximum less than five hundred cells to the liter.

GENERAL PRODUCTIVITY BELOW THE SURFACE

Subsurface samples were taken at three stations in this section in locations differing considerably in relationship to shores and currents. One was well out toward the middle of Santa Barbara Channel, another near the middle of the northerly entrance to Santa Cruz Channel, and the other near the middle of Santa Cruz Channel a little southeast of its median point. (For major geographic features see figs. 1, 5.)

The subsurface production was heavy at the northerly end of Santa Cruz Channel, very good near its middle, and poor toward the middle of Santa Barbara Channel. The same species were found at all three stations, except that they were fewer where total numbers were smaller. So far as it goes the evidence indicates that conditions for production were exceptionally favorable in or about Santa Cruz Channel.

The Individual Stations

Station D65.

This station was nearly four miles northeast of Santa Rosa Island pier. Since collections and observations were taken while drifting, the position was not precisely determined. At the beginning of the work it was a little nearer to the northeast point of Santa Rosa Island than it was to the pier or to Santa Cruz Island, but the greater part of the collecting was done midway between the two islands. The water was not deep enough to permit taking catches below thirty meters. It is probable that the average depth through the distance drifted was a little more than thirty meters.

As shown by figure 4, column D65, there was a remarkable similarity in the magnitude of the catches of diatoms at all of the levels from surface to bottom at intervals of five meters. It is true that this similarity is exaggerated somewhat by the use of logarithms and by

the small scale necessary for the figure. The smallest catch (at surface) was over seven hundred thousand cells to the liter, and the largest (at fifteen meters) was over one million two hundred thousand. All of the catches would rate as large in most series of collections.

The numbers of dinoflagellates were very small, less than 1,000 cells to the liter at all levels.

TABLE 10

SEVEN LEADING SPECIES AT D65

Meters	Chaetoceras compressum (Laud.)	Chaetoceras debile Cl.	Chaetoceras scolopendra (Cl.)	Chaetoceras sociale Laud.	Chaetoceras sp.	Nitzschia seriata Cl.	Thalassiothrix frauenfeldii (Grun.)
0	110,500	73,750	74,750	49,750	121,300	147,000	156,000
5	98,000	73,000	176,000	41,600	145,800	140,000	179,000
10	11,200	34,800	262,000	119,000	183,000	155,000	170,000
15	109,000	172,000	219,000	107,600	265,000	111,000	195,000
20	3,600	61,200	207,000	70,000	165,400	129,000	153,000
25	2,400	82,000	172,000	108,000	157,000	103,000	207,000
30	75,000	89,000	103,000	31,000	211,000	150,000	214,000
Total for 7 levels	409,700	585,750	1,213,750	526,950	1,248,500	935,000	1,274,000
Average for 7 levels	58,530	83,678	173,393	75,278	178,357	133,571	182,000

The most prominent species of diatoms—

Of the thirty species represented seven appeared in numbers of one hundred thousand or more cells to the liter at one or more levels (table 10). At first glance all of the seven species seem to have had an approximately uniform distribution through the seven levels. However, detailed comparison shows that the largest numbers of *Chaetoceras compressum* Laud. were taken at the surface, and that *C. scolopendra* Cl., *C. sociale* Laud., and *Nitzschia seriata* Cl. showed a larger aggregate for the three levels above fifteen meters than they did for those below. *Chaetoceras debile* Cl., *C.* sp., and *Thalassiothrix frauenfeldii* (Grun.) had larger representation below fifteen meters than they had above. It is notable that all the seven species were strongly represented at the fifteen-meter level and that some showed a maximum there, enough to fix the total maximum at that level.

Some individual species of diatoms—

Thalassiothrix frauenfeldii (Grun.) was clearly the most important form. It was not lower than third in numerical representation at any level sampled and in actual volume it was predominant at all. The catches of this species at different levels had a notable likeness

in magnitude, all of the seven catches being within 20 per cent of the mean. As compared with the tendencies shown at stations 1 and 2 (fig. 3), this is contradictory since the general indication there was that the species thrived best at lower levels. Probably this difference is to be explained by the fact that station D65 was in relatively shallow water and in a locality characterized by strong mixing action of water currents. Even here the production was slightly greater at the lower levels.

Chaetoceras sp. was second in number of cells produced but most of these cells were small.

Chaetoceras scolopendra (Cl.) was third in number of cells produced. These were also small, apparently averaging less than one-third of the size of typical cells of *Thalassiothrix frauenfeldii* (Grun.).

Nitzschia seriata Cl. was fourth in numerical representation but, since its cells were considerably larger than those of the *Chaetoceras* forms just discussed, it probably ranked second in mass production. It agreed with *Thalassiothrix frauenfeldii* (Grun.) in showing somewhat similar numbers at all levels, but with maximum production below the surface. Its numbers here support the indications of many other records that it has a prominent place in production in California waters.

General comment—

Taking the series of catches at D65 as a whole, the outstanding feature seems to be that a large population and a large number of species were distributed with exceptional uniformity through a depth of thirty meters which involved great differences in indefinite numbers of environmental factors, physical, chemical, and biological.

Upon examination of the physical factors open to investigation under the conditions of operation in this cruise, it was found that they, as well as the plankton catches, showed strong similarity at the different levels (table 11). This is particularly true in the case of temperature which showed less than one degree Centigrade difference between the thirty-meter level and the surface. Since the temperature at all levels was approximately that of the twenty-meter level at stations in deeper water it seems certain that station D65 marked a point of mixing of water from many levels.

While the evidences of stratification (as indicated in discussion of individual species) were not very strong they did appear to some extent in spite of the general mixing effect in the locality. If we accept the ordinary assumption (which is supported by some evidence), that water stirred from the bottom increases the supply of nutritive material for diatoms, we may suppose that many species of

these plants would find plenty of nutriment at this station, and that they would tend to stronger development at the levels with the most favorable intensity of light. But tenure of these levels, either higher or lower, would be disturbed by the mixing currents and the showing would be variable and erratic. So far as the single series at this station is concerned, the notable features of production and distribution may be almost entirely clarified through consideration of the effects of extensive mixing of waters from several levels.

TABLE 11

PHYSICAL RECORDS AT CERTAIN STATIONS

Meters	0	5	10	15	20	25	30	40	50
Station D65 (4 miles, cruise) August 21									
Temperature	15.10	15.90	14.78	14.72	14.73	14.60	14.45	.....	.....
Salinity	33.58	33.64	33.67	33.64	33.73	33.74	33.62	.....	.....
Station 2 (5 miles, La Jolla) July 22									
Temperature	20.35	20.30	19.55	18.95	17.20	16.10	14.90	.....	.....
Salinity	33.68	33.67	33.71	33.58	33.48	33.50	33.49	.....	.....
Station D73 (10 miles, cruise) August 21									
Temperature	18.62	.....	17.45	.....	14.70	.....	12.90	11.80	11.00
Salinity	33.61	.....	33.58	.....	33.54	.....	33.53	33.55	33.60
Station 1 (10 miles, La Jolla) July 22									
Temperature	20.72	.....	18.80	.....	16.42	.....	14.10	12.82	11.60
Salinity	33.71	.....	33.66	.....	33.50	.....	33.48	33.49	33.57
Station D115 (2 miles, Cruise) August 23									
Temperature	17.95	17.50	16.10	12.90	12.93	.....	12.05	11.40	.....
Salinity	33.55	33.64	33.55	33.53	33.51	.....	33.58	33.69	.....
Station D102 (5 miles, cruise, Pt. Conception) August 23									
Temperature	17.20	16.45	13.60	12.80	12.10	11.83	11.30	10.90	10.83
Salinity	33.62	33.58	33.58	33.55	33.47	33.48	33.48	33.50	33.61

Station D73.

Like D65, station D73 (11 miles northeast of Santa Rosa Island pier) showed somewhat similar numbers at its different levels (all much smaller than at D65, it is true). It had noticeably fewer numbers at twenty meters than those in the catches next above and below that level (4,480 *vs.* 10,560 and 12,640). There were very few species at this station (seven species and two catchall groups) and the smaller catch at twenty meters was due to smaller numbers of the two leading forms, *Thalassiothrix frauenfeldii* (Grun.) and *Nitzschia seriata* Cl. The latter had its maximum at ten meters and the former at thirty meters. *Chaetoceras* sp. was next with a maximum at ten meters. The largest total of all species was at thirty meters. Dinoflagellates were almost entirely absent.

The general production at this station was much like that of stations 1 and 2 (fig. 2) about the middle of July, especially in the fact that it was not strong at any level, although fairly well sustained down to fifty meters. It is possible that this resemblance in August to production of the other stations in July may be due to a seasonal lag dependent upon geographic location. At any rate, the poor production at this offshore station in August supports the evidence at stations 1 and 2 (see page 213) that production tends to be poor at offshore stations after midsummer.

The distribution of physical conditions investigated agreed with that of the diatoms in showing a similarity to station 1 in July and a dissimilarity with that of D65 taken less than four hours before (table 11, D73). At both of the ten-mile stations (1 and D73) the temperatures, though differing in actual readings, ran through similarly regular series of gradations from higher to lower as the depths increased but, at the four-mile station (D65, in relatively shallow water) the gradations were not so regular and their magnitude was practically negligible. Therefore, it appears that D73 showed more nearly than D65 the conditions of the open sea without immediately recognizable influences from land.

Station D115.

Station D115 (fig. 5) was located less than two miles from the nearest point of land a little south of the middle of Santa Cruz Channel. The depth of water where the work was begun was about fifty meters. At the finish it was near one hundred meters. The main drift in the locality was toward deeper waters, the temperature and salinity varying from level to level in about the same way as is usual in water not subject to mixing movements.

There was moderately good production of diatoms at all levels, but dinoflagellates were almost entirely absent. Only four subsurface levels were sampled.

Some prominent species of diatoms—

Of the twenty-four species of diatoms recorded there were six which yielded 1,000 or more cells to the liter at three or more levels.

The catchall group, *Chaetoceras* sp., showed greatest abundance with a maximum of 45,000 cells to the liter at ten meters. The catch at twenty meters was almost as large. In fact, this group led in production at every level. *Chaetoceras debile* Cl., *Thalassiothrix frauenfeldii* (Grun.), *Nitzschia seriata* Cl., *Chaetoceras scolopendra* (Cl.), and *C. sociale* Laud. ranked in the order named. The first one of these had a maximum at thirty meters, the next two had maxima at ten meters, and the last two at five and twenty meters, respectively.

The general indication of the records is that the leading four groups were in slightly greater abundance below ten meters than they were above it, but since the series ran only to the thirty-meter level the meaning of this is not very definite. However, since this indication agrees to a considerable extent with indications from other series it may be tentatively assumed that there was a tendency at the locality of this station in August for diatoms to reach maximum production ten or more meters below the surface, and for some species to reach maxima at lower levels than others.

6. Point Conception Section

All of the twelve stations in this section were located near a line from the northeast point of Santa Rosa Island to Point Conception. Subsurface catches were taken at only one station. Five stations were occupied on the outgoing trip on August 22, the others on the return trip, August 23.

GENERAL PRODUCTIVITY AT THE SURFACE

The numbers of both diatoms and dinoflagellates were small, the former far less and the latter slightly less than in the Santa Rosa Island section. The largest catch of diatoms (18,760 cells to the liter) was taken about five miles south of Point Conception in a strong drift current to the northwest. Only one catch of dinoflagellates exceeded five hundred cells to the liter, a number too small to consider except as indicating presence of the group.

Species of Diatoms

Twenty-six species of diatoms were noted, most of them represented by very small numbers. Only three were regularly present in all of the catches. These all had maxima at station D102, about five miles south of Point Conception. *Chaetoceras* sp. was in the lead with a maximum of nearly six thousand cells to the liter. *Thalassiothrix frauenfeldii* (Grun.) was second with a maximum a little over three thousand, and *Nitzschia seriata* Cl. was third, although it had a maximum slightly more than four thousand. In this section there is some indication that surface productivity is best slightly offshore.

GENERAL PRODUCTIVITY BELOW THE SURFACE

Subsurface catches were made only at station D102, about five miles south of Point Conception. The boat drifted northwestward about a mile while taking the series. This was at the western entrance to Santa Barbara Channel where the water was over three hundred meters in depth. A full series of catches was taken down to sixty meters (fig. 4, column D102).

Indications from this station were that productivity was far better below the surface than at the surface. Two subsurface levels showed totals of diatoms more than ten times as great as that at the surface, one was over five times as great, and two were twice as great. The maximum of total production appeared at fifteen meters (223,640 diatom cells to the liter) but the number at ten meters was close to that and the number at five meters half as large. The steadily decreasing numbers at lower levels indicated that the sinking of decadent individuals did not play a notable part in distribution in this series. Evidently, conditions for diatom production at that time and locality were most favorable at levels not far below the surface.

The Most Prominent Species of Diatoms

Of twenty-four species of diatoms five had notable prominence in subsurface production. Three of these had maxima at fifteen meters, two at ten meters. The lead in production was taken by *Chaetoceras* sp. which had a maximum (60,960 cells to the liter) at fifteen meters. The other four prominent species each had a total for the series not far from one hundred thousand cells to the liter. *Chaetoceras debile* Cl. and *C. scolopendra* (Cl.) had maxima at ten meters, while *Nitzschia seriata* Cl. and *Thalassiothrix frauenfeldii* (Grun.) had maxima at fifteen meters. The evidence at this station indicates a tendency of the productive species to reach their maxima at nearly the same level.

Ten other species which appeared in several catches had maxima at fifteen meters or above. No important species had a maximum below that level. Considering this feature in connection with the distribution of the leading species it seems that this station had a well developed depth boundary at about fifteen meters, marking off an upper, favorable zone from a lower zone less favorable.

General Comment

The most impressive feature of the August cruise was the higher productivity in the northerly sections. It is true that the Gulf of Santa Catalina was not sampled below the surface on the cruise, but the series from stations 1 and 2 a few days before were probably as nearly representative of the section as the few stations occupied for subsurface work in other sections. In the former the subsurface catches were much lighter than most of those in the Santa Rosa Island and Point Conception sections. Compare figure 2 with figure 4.

TABLE 12

RANK OF FIVE PROMINENT SPECIES IN GEOGRAPHIC SECTIONS

Rank	Sections					
	Gulf of Santa Catalina	Santa Monica Bay	Pt. Hueneme	Santa Barbara	Santa Rosa Island	Pt. Conception
	Surface catches					
1	Hemiaulus hauckii Grun.	Leptocylindrus danicus Cl.	Leptocylindrus danicus Cl.	Chaetoceras sp.	Chaetoceras sp.	Chaetoceras sp.
2	Chaetoceras sp.	Thalassiothrix acuta Karst.	Chaetoceras sp.	Nitzschia seriata Cl.	Skeletonema costatum (Grev.)	Thalassiothrix frauenfeldii (Grun.)
3	Asterionella japonica Cl.	Chaetoceras sp.	Thalassiothrix acuta Karst.	Chaetoceras scolopendra (Cl.)	Thalassiothrix frauenfeldii (Grun.)	Nitzschia seriata (Cl.)
4			Nitzschia seriata Cl.	Thalassiothrix frauenfeldii (Grun.)	Nitzschia seriata (Cl.)	
5			Thalassiothrix frauenfeldii (Grun.)	Rhizosolenia setigera Btw.	Chaetoceras debile Cl.	
	Subsurface catches					
1		Thalassiothrix frauenfeldii (Grun.)	Thalassiothrix frauenfeldii (Grun.)		Thalassiothrix frauenfeldii (Grun.)	Chaetoceras sp.
2		Chaetoceras sp.	Chaetoceras sp.		Chaetoceras sp.	Thalassiothrix frauenfeldii (Grun.)
3		Chaetoceras scolopendra (Cl.)	Chaetoceras scolopendra (Cl.)		Chaetoceras scolopendra (Cl.)	Nitzschia seriata (Cl.)
4		Nitzschia seriata (Cl.)	Nitzschia seriata (Cl.)		Nitzschia seriata (Cl.)	Chaetoceras scolopendra (Cl.)
5		Thalassiothrix nitzschioides Grun.				Chaetoceras debile Cl.

As already indicated in the detailed discussion, mixing probably played a major part in this higher productivity, but it is also possible that seasonal lag connected with a little higher latitude had some influence. It is also probable that geographical contours, both of sea floor and of adjoining land, had considerable influence, especially if we consider the generally rougher movement of the water in higher latitudes. Furthermore, to me it seems highly desirable constantly to

bear in mind the problem of relationship of functional (vegetative and propagative) vigor of one or more species to coincidence (in time and place) with an indefinite number of other favorable factors. The unsolved problem of intensities of effective light is also highly important. In the main, the evidence of this cruise favors the commonly accepted view that productivity increases with advance into higher latitudes.

A feature of interest, although possibly lacking importance, is the distribution of leading species of diatoms in the different sections. Those listed in table 12 were found to greater or less extent in every section. In the thin populations at the surface in the Gulf of Santa Catalina section, *Hemiaulus hauckii* Grun. and *Asterionella japonica* Cl. exhibited a prominence which they did not hold in other sections, although both appeared in numbers considerably larger in the heavy populations of the Santa Rosa Island section. *Thalassiothrix frauenfeldii* (Grun.), which had been decreasing in numbers at stations 1 and 2, was poorly represented in the stations of the Gulf of Santa Catalina covered by this cruise and it was not prominent in surface catches until Santa Monica Bay was passed. *Nitzschia seriata* (Cl.) showed similar characteristics in this series. On the other hand, considering the summer of 1926 as a whole, these two species gave remarkable evidence of importance in productivity from Point La Jolla to Point Conception. Compare table 12 with tables 4 and 8 and figure 2.

Summary

1. Production of diatoms was highest in the immediate vicinity of Santa Rosa Island, both at the surface and below.

2. Production of diatoms in general was better in the more northerly sections.

3. Production of diatoms was generally best at subsurface levels, when they were sampled, maximum production being at about ten to twenty meters in shallow waters, twenty to thirty meters in deeper waters.

4. Favorable influences of Los Angeles sewage effluents may be indicated by a maximum of diatom production near Point Vincente in the Santa Monica Bay section.

5. The general indication is that production is likely to be better within a few miles of or close to shore.

6. No notable differences appeared in the species of diatoms or dinoflagellates represented in the different sections of the cruise but there were differences in the relative prominence of species of diatoms in the different sections, the northerly sections showing a relative prominence of species similar to that of stations 1 and 2 in June–July.

7. Dinoflagellates were very poorly represented at all stations and all depths.

8. Although the evidence from this series is interesting, suggestive, and instructive, it is clear that much more must be accumulated before it can be regarded as truly representative of the territory.

9. It is evident that the methods of collecting have been improved to such an extent that they can be carried continuously and dependably through any ordinary conditions of operation.

MISCELLANEOUS COLLECTIONS

The term "miscellaneous collections" includes those catches taken in very short series or else at irregular periods which prevent their treatment in a more definite way. On the basis of geographical location they may be assigned to two sections: 7, the San Nicolas Island section, visited in March, 1926, by McEwen while making an observational trip with the United States Coast and Geodetic Survey steamer "Pioneer." Catches in this series were mostly taken between San Nicolas and Santa Barbara islands and in San Pedro Channel near Point Vicente; 8, the San Diego section, in which the catches were obtained at more or less irregular periods between the San Diego Yacht Club mooring in San Diego Bay and stations 1 and 2 off La Jolla. For general location of both sections see figure 1, the general map.

7. San Nicolas Section

Forty-one surface catches were made in this section as opportunity was found in connection with other oceanographic observations. A few were taken on March 15, 16, 17, but most were taken on March 18 and 19, after which they had to be discontinued on account of stormy weather.

GENERAL PRODUCTIVITY

Production at the surface was not very good for either diatoms or dinoflagellates in this territory at this time. The maximum of diatoms was about thirty-one thousand cells to the liter at a point about ten miles north of San Nicolas Island. Four other catches nearly as large were taken in the same general locality, some a little closer to the island. In fact, all the catches yielding more than ten thousand diatom cells to the liter were taken within about ten miles of either San Nicolas Island or Point Vincente. Two catches of diatoms showed less than one thousand cells to the liter. One of these was taken about ten miles south of Point Dume, the other about ten miles from Point Vincente.

The occurrence of diatoms in numbers of some thousands to the liter over an area extending to nearly one hundred miles from shore showed that the region was far from barren at this time. Rather, one may suppose that conditions for propagation were tolerable but not stimulative. Since San Nicolas Island is an exposed point of a submarine ridge extending east of southward from Santa Rosa Island it is probable that upwelling had important influence in the higher production of its locality. In the general locality of Point Vincente the slightly higher production may have been due to upwelling and to the influence of the Los Angeles sewage effluents of the Santa Monica Bay section.

The numbers of dinoflagellates were still smaller than those of the diatoms. Only four catches were greater than one thousand cells to the liter and these were all in the region of Point Vincente.

Species Represented

Fifty-five species of diatoms were represented, most of them in several or many catches. This large number of species, so widely distributed, is strongly confirmatory of the indication that conditions were generally tolerable but not stimulative to production.

Four groups of diatoms were notably prominent and continuously represented in numbers throughout the series of catches. In the order of numerical rank they were *Chaetoceras* sp., *C. scolopendra* (Cl.), *C. compressum* Laud., and *Hemiaulus hauckii* Grun. These *Chaetoceras* forms are commonly found in the southern California territory, often in vastly larger numbers than they showed in this series. Their appearance here is confirmatory of indications from other series that they are important contributors to production in the general area. On the contrary, *H. hauckii* has formerly appeared to be a rare and poorly productive species. Its maximum in this series was only about 4,600 cells to the liter, but that is so much greater than has been recorded heretofore in studies at the Scripps Institution that it constitutes a conspicuous feature in the records for 1926 (Cf. *H. hauckii*, p. 216). The species was fairly evenly distributed in the San Nicolas series.

Only two species of dinoflagellates appeared in notably greater numbers than others of the twenty-eight represented. These were *Ceratium furca* (Ehr.) and *Gonyaulax polyedra* Stein. Both had maxima of about one thousand in the Point Vicente locality. They are commonly found in the southern California territory, the last named being responsible for some of the much discussed cases of "red water" in earlier years.

8. San Diego Section

Ninety surface catches, distributed over a period of seven months but mostly taken in spring and early summer, were obtained at miscellaneous stations in this section. Twenty-five subsurface catches were taken in March and May (fig. 4). All of these catches may be roughly assigned to two basic localities: Point Loma and station 1 (ten miles off La Jolla pier). A ten-mile radius from each of these points will include all of the miscellaneous stations except station 3 which was about thirteen miles nearly southwest of Point Loma.

GENERAL PRODUCTIVITY

Most of the surface catches of diatoms were small, many of them very small, consisting of only a few hundred cells to the liter. The only exception to this was in the vicinity of Point Loma where one catch at the whistling buoy station in September showed nearly six hundred thousand cells to the liter, and one near the bell buoy station in August showed nearly seventy thousand cells to the liter. Only one other catch was as great as twenty-three thousand cells to the liter. This (35,436) was taken at station 1 on June 17. A casual survey of the manuscript column of numbers of total diatoms shows that the only localities in which a total of 10,000 cells was reached or exceeded were near Point Loma, at stations 1 and 3.

Records from the whistling buoy station in the Point Loma locality have been obtained in two earlier years, 1922 and 1924 (Allen, 1923*b*, Sleggs, 1927). On June 21, 1922, a surface catch of 864,000 diatom cells to the liter was made and a subsurface catch of twenty-five meters of 3,300,000 cells. In 1924 on May 8 a surface catch of more than 100,000 diatom cells was made. While this was small as compared with that of 1922 it was large as compared with other stations in 1924. The uniform showing of superior productiveness of this locality for the three seasons in which it was sampled is strongly indicative that it is normally highly productive.

Species of Diatoms Represented

Thirty-six species of diatoms were recorded, most of them present in many different catches. As in the case of section 7 the widespread occurrence of so many different species indicates that there was sufficient seeding of the area. It also seems to indicate that there was no unusual development of injurious influences, since it is probable that directly injurious influences would have completely eliminated many

of these species. Wherefore, it seems probable that poor production in the general territory was due to lack of food, or lack of stimulating influences, or to some lack of a similarly general type.

Four species showed prominence sufficient to attract attention, two because of constancy of representation in moderate numbers and two because of one or a few large catches. The two fairly constant in representation were *Chaetoceras* sp. and *Hemiaulus hauckii* Grun. The more sporadic in appearance were *Asterionella japonica* Cl. and *Chaetoceras debile* Cl., both taken in exceptional numbers (as to this series) near the entrance to San Diego Bay, where they have shown similar records in other years. Of these four more prominent forms, *H. hauckii* is the only one making a better showing than might be expected from its previous records.

Representation of Dinoflagellates

Only three surface catches of dinoflagellates exceeded one thousand cells to the liter. These were all near Point Loma. There was no notable feature in distribution of the few individual species represented.

PRODUCTIVITY BELOW THE SURFACE

So far as the miscellaneous subsurface catches were concerned, production was uniformly poor, the largest single catch of diatoms (7,760 cells to the liter) being at station 3 (about thirteen miles southwest of Point Loma) on March 30 (fig. 6).

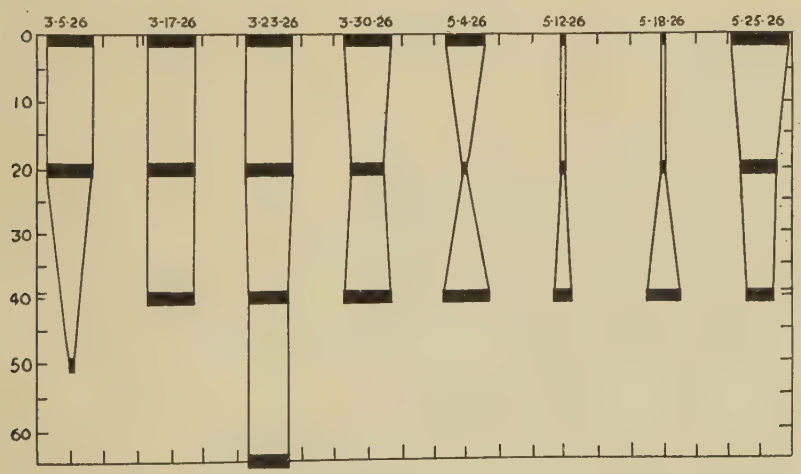

Fig. 6. Miscellaneous subsurface catches near San Diego. Cross-bars represent logarithms of numbers of diatom cells per liter. Numerals indicate dates, and depths in meters.

In most of the subsurface catches dinoflagellates were so few that they escaped notice. The largest catch was only 160 cells to the liter.

Subsurface samples were taken twice at station 1 in March and six times at station 3 in March and May (fig. 6).

Summary

1. Production was generally poor, indicating a poorly productive season.

2. The only catches of notable size (two in number) were taken within two or three miles of land at the entrance to San Diego Bay. Similar conditions in 1922 and 1924 (Allen, 1923*b*, Sleggs, 1927) indicate this to be an especially productive locality, probably because of its proximity to land and the effluents of urban drainage.

3. The prominence of *Hemiaulus hauckii* Grun. in 1926 was unique in the history of the southern California territory for the five seasons studied.

4. There was some evidence of the favorable effects of upwelling in the vicinity of San Nicolas Island.

GENERAL SUMMARY

1. So far as the collecting of phytoplankton by boat was concerned, 1926 was the most successful season in the history of the Scripps Institution. This success was evidently due to two features in policy: (*a*) the adoption of a program of investigations having demands well within the limits of available facilities; (*b*) the use of light and simple apparatus which could be operated rapidly without straining the boat equipment and without undue impediment to concurrent investigations of other phenomena.

2. Production of diatoms was generally poor, or only moderate, off the southern California coast south of Point Dume in 1926.

3. Production of dinoflagellates was very poor in all catches made in southern California waters in 1926.

4. There was strong indication of maximum production of diatoms at levels fifteen to thirty meters below the surface in this region in the summer.

5. Production at the surface level usually gives a fairly good indication of the productivity of a locality in diatoms and dinoflagellates at a particular time.

6. Most of the prominent diatoms were distributed through different levels above and below the level supporting their maxima.

7. The wide range of tolerance shown by individual species of diatoms is a warning to observe caution in assigning to them narrow limits of distribution in response to single factors of the environment.

8. Favorable influence of upwelling is suggested for some localities in the southern California territory.

9. Some of the evidence in 1926 indicates favorable influence of nearness to land and to products of drainage from urban centers of human population.

10. In the La Jolla region the station ten miles to seaward was more productive in the summer of 1926 than the station only five miles to seaward from the Scripps Institution pier.

11. Production of diatoms appeared to be superior in northernmost sections off the coast of southern California in 1926.

12. Production of two species, *Thalassiothrix frauenfeldii* (Grun.) and *Hemiaulus hauckii* Grun., was exceptionally prominent in 1926, relative both to former occurrence in Scripps Institution collections and to concurrent representation of other species.

13. For five seasons, less than a score of species of diatoms have had prominent places in production in southern California waters.

14. For five seasons the general production of dinoflagellates has been only moderate, or poor. The few localized or sporadic exceptions merely serve to emphasize the general impression.

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